CS 331 Midterm
Spring 2015

You have 50 minutes to complete this midterm. You are only allowed to use your textbook, your notes, your assignments and solutions to those assignments during this midterm. If you find that you are spending a large amount of time on a difficult question, skip it and return to it when you’ve finished some of the easier questions. Total marks for this midterm is 46.

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Section I: Agents (8 points)

1. Suppose you had a resolution refutation agent designed to answer questions of the form “does $KB \models \alpha$?” where $\alpha$ can be any sentence in propositional logic and all of the sentences in the KB are in propositional logic. You may assume that you have enough computational resources that the agent will give you an answer.

For each part below, circle the choice which best describes the environment for the resolution refutation agent:

a) Fully observable or Partially observable [1 point]

b) Deterministic or Stochastic [1 point]

c) Episodic or Sequential [1 point]

d) Static or Dynamic [1 point]

e) Discrete or Continuous [1 point]

f) Single agent or Multi-agent [1 point]

2. What type of agent is the best agent for the resolution refutation agent? Choose from simple reflex agent, model-based reflex agent, goal-based agent and utility-based agent. Explain your answer. [2 points]

A goal-based agent would be ideal because all you need is to get to the empty clause. However, I will accept utility-based and model-based here.
II. Search [12 points]

3. The following questions deal with results from running breadth-first search (BFS), depth-first search (DFS), iterative deepening depth-first search (ID-DFS) and A-star search on the 8-tile puzzle. These results are similar to what you reported for Programming Assn1 and summarize the number of nodes on the solution path and the number of nodes expanded (ie. the number of nodes removed from the fringe and expanded). All algorithms use a closed list and the step cost (the cost of moving from a node to its immediate neighbor) is always 1.

a) Suppose BFS is implemented correctly. Is it possible for DFS to find an optimal solution path but expand fewer nodes than BFS? Explain your answer for full credit. [2 points]

Yes is is possible if DFS gets lucky and finds the goal first eg. on the leftmost path.

b) Suppose ID-DFS is implemented correctly, including proper updating of the closed list for multiple paths to a previously visited node. Is it possible for DFS to find a solution path with a lower number of nodes than the solution path found by ID-DFS? Explain your answer for full credit. [2 points]

No it is not possible because ID-DFS is optimal.

c) Suppose you implement A-star search with $f(n) = h^*(n)$, where $h^*(n)$ is the actual cost (not the estimated cost) of the path from the node n to the goal node. Assume that $h^*(n)$ is given to you by an oracle. Will this version of A-star search produce an optimal solution? Explain your answer for full credit. [2 points]

No it is not optimal because this is still greedy best-first search.
d) Suppose you implement two versions of A-star search – one using heuristic \( h_1 \) and the other using heuristic \( h_2 \). Both heuristics are admissible, but for all nodes \( n \), \( h_2(n) > h_1(n) \). Which heuristic expands more nodes? [2 points]

\( h_1(n) \) will expand more nodes.

4. Suppose you have two options for solving a problem: (i) A-star search with a good heuristic function and (ii) a local search algorithm (eg. hillclimbing or simulated annealing). When would you prefer using (i) over (ii)? [2 points]

If you needed the exact optimal solution (not an approximate or a “close but not quite optimal one”) then option (i) is best.

5. Name one advantage that genetic algorithms have over simulated annealing. [2 points]

The representation is richer and allows for more complex moves through the search space with the crossover operator.
III. Games [8 points]
6. This question deals with the game tree shown below. The leaf nodes contain the utility values, with X and Y being variables.

a) Give values to X and Y such that the alpha-beta algorithm performs the maximum amount of pruning. [4 points]

\[ X \leq 5, Y \leq 5 \]

b) Indicate which branches would be pruned by your answer in part (a) by crossing them out on the diagram above. [2 points]
7. In Programming Assignment #2 (4x4 Othello), why did you not need to use evaluation functions for the game tree? [2 points]

The entire game tree fits into memory.

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IV. Propositional Logic [18 points]

8. In the diagrams below, the gray oval corresponds to the space of models in which KB is true. The white oval corresponds to the space of models in which A is true. Which of the diagrams below (answer with 1, 2, or 3) corresponds to $\mathbb{KB} \models A$? [2 points]

(1) (2) (3)

(2) is correct. Recall the definition of entailment: in all the models in which KB is true, A is also true.

9. We covered the resolution operator in class but never proved it. For this question you will prove that performing resolution on $(X \lor Y)$ and $\neg X$ produces $Y$. To do this, prove that $(X \lor Y) \land \neg X \implies Y$ is valid. [6 points]

\[
\begin{align*}
(X \land \neg X) \lor (Y \land \neg X) & \implies Y \\
\equiv false \lor (Y \land \neg X) & \implies Y \\
\equiv (Y \land \neg X) & \implies Y \\
\equiv \neg (Y \land \neg X) \lor Y & \\
\equiv \neg Y \lor X \lor Y & \equiv true
\end{align*}
\]
10. Among the people you would like to invite to a party are four touchy friends. You know that if Leonard or Howard attends, Sheldon will not attend, Sheldon will attend only if Raj will be there, and Raj will attend only if Leonard and Howard attend.

a) Write out the knowledge base in CNF. [5 points]
The three sentences are:
1. \( L \lor H \Rightarrow S \)
   \( \neg(L \lor H) \lor S \equiv (\neg L \land \neg H) \lor S \equiv (\neg L \lor S) \land (\neg H \lor S) \)
2. \( S \Rightarrow R \)
   \( \neg S \lor R \)
3. \( R \Rightarrow L \land H \)
   \( \neg R \lor (L \land H) \equiv (\neg R \lor L) \land (\neg R \lor H) \)

The KB in CNF is:
- \( \neg L \lor S \)
- \( \neg H \lor S \)
- \( \neg S \lor R \)
- \( \neg R \lor L \)
- \( \neg R \lor H \)

b) Using the resolution refutation algorithm, determine if the KB entails that Sheldon does not attend the party. Show the intermediate steps for partial credit. [5 points]

Does \( KB \models \neg S \)?
Add \( S \) to the KB:
1. \( \neg L \lor S \)
2. \( \neg H \lor S \)
3. \( \neg S \lor R \)
4. \( \neg R \lor L \)
5. \( \neg R \lor H \)
6. \( S \)

From (6) and (1):
7. \( \neg L \)

From (7) and 4)
8. \( \neg R \)

From (8) and 3)
9. \( \neg S \)

From (6) and (9) you get the empty set.
Therefore, \( KB \models \neg S \)